RESEARCH UPDATES 2017-2020

forWater

NSERC Network for Forested Drinking Water Source Protection Technologies

Designed & written by Elanor Waslander, Knowledge Mobilization Manager for the *for*Water Network, in collaboration with Network researchers and partners.
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RESEARCH AT A GLANCE

The *for*Water Strategic Network is contributing critical new knowledge and technologies needed to ensure safe drinking water in a world affected by climate change.

Researchers work with industry and government partners to seek out innovative solutions and build resilient, adaptive communities.

Midway through the Network's timeline we are sharing preliminary research findings which start to paint the picture for future water treatability and source water protection to ensuring safe drinking water for large and small communities across Canada.

Interdisciplinary research spanning

7 Staff

23 Researchers

43 Young professional Master's and PhD students

45 Industry partners

9 Collaborative Universities

4 Research Themes

*for*Water Network Research

4 **Water utilities**

5 **Watershed research sites across 5 major forested ecozones**

"The forWater Network is breaking new ground in addressing the ever-increasing need to protect drinking water from increasing wildfires, floods, and hurricanes. We're working towards providing safe drinking water across Canada."

MONICA EMELKO
PRINCIPAL INVESTIGATOR OF THE *for*WATER NETWORK

@forWaterNetwork forwater.ca

*for*Water Network Impact

101 Research presentations sharing findings

$9M Additional funds secured (CFI & prov. matching)

18 Young professional training sessions

91% Increase in Twitter followers

18 Undergraduate lab support semesters

3 Graduated students (since December 2020)

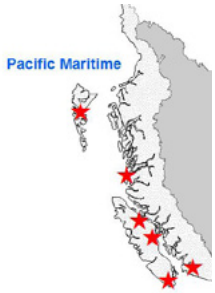
Alumni from the Network find work with government, water utilties, and research groups in their field!

Not only is it vital to all biological functions on earth, water links abiotic and biotic, connects the earth to the atmosphere, and creates a dynamic fluid continuum between ecosystems. Water connects our world; it must be respected, protected and managed equitably and sustainably."

HANNAH MCSORLEY
UNIVERSITY OF BRITISH COLUMBIA
*for*WATER NETWORK GRADUATE & ALUMNI

Theme 1: Watershed Science & Forest Management

Ecozone: Pacific Maritime

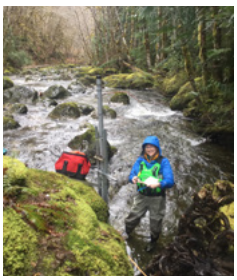


Characterized by coastal mountains with high to very high rainfall, the research conducted in British Columbia's forests is looking to understand the impact of BC's forest management on drinking water treatability, specifically looking at differing dissolved organic carbon (DOC) concentrations and compositions.

Studying the impact of storm flow on DOC dynamics

A study by Johnson and MSc graduate Mistick published in the Journal of Hydrology found the DOC response to storms to be larger and faster at the clear-cut site, while low-flow DOC concentrations were lower in the clear-cut site. Using high frequency measurements of DOC and related hydroclimatic data, they found that low antecedent flow and greater storm intensity in the clear-cut site led to its significantly elevated DOC storm response compared to the forested site.

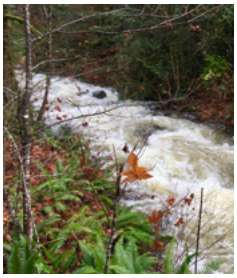
Theme 1



Natural organic matter dynamics in Greater Victoria watershed

Research led by Floyd, Johnson, and MSc graduate McSorley on Vancouver Island showed flow conditions were found to drive variation in water quality. The source, and molecular character of natural organic matter (NOM) changes with the seasons indicating potential seasonality to treatment requirements. Antecedent wetness conditions linked stream water quality to distant NOM source pools. Groundwater-surface water dynamics, sub-surface geological features play an important role in surface water quality dynamics. Overall, the relationship between forest harvest history and water quality are complex and require further research.

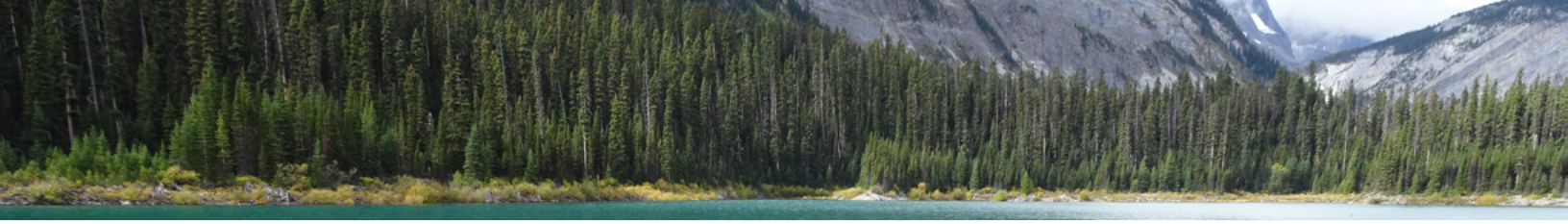
Theme 1



Forest harvest effects on drinking water quality and treatability in the Comox Lake watershed

Research led by Tank, Floyd, MSc candidate Bourgeois in collaboration with Emelko and Senior Chemist Amiri indicates that DOC and total suspended solids (TSS) are overall low in streams draining to Comox Lake, indicating low drinking water concerns from these parameters during baseflow conditions. Stormflow increases both DOC and turbidity substantially, with strong correlation between DOC-associated metrics (e.g., UVA_{254}) and disinfection byproducts (DBPs).

Theme 1 Theme 3



Ecozone: Montane Cordillera

With features like high elevations, steep topography, high annual precipitation, and deep mountain snowpacks, the hydrology of this region of Alberta is complex. Research evaluates and compares sustainable forest harvest strategies' impacts on hydrology, and water quality that collectively affect drinking water treatability, from smaller headwaters areas to larger river basin scales and across different temporal scales from harvesting.

Alternative forest management strategies show minimal impact on water quality and drinking water treatability

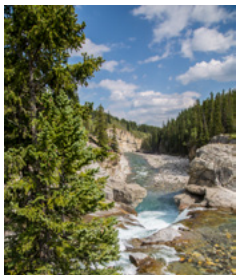
Research led by Silins, Williams, Cherlet in collaboration with Stone, Emelko and MSc graduate Bahramian looked at ongoing results from evaluation of three alternative harvest strategies showing no deterioration of water quality or drinking water treatability after harvest. In contrast, interim results after severe wildfires show large, and persistent impacts on water quality including key treatability metrics for three years after the Kenow wildfire. Early synthesis of these findings support the broader potential use of best management practices used by Canfor in the study watersheds in forest harvest operations elsewhere in Canada.

Theme 1 Theme 2 Theme 3

High DOC in pore water not coupled from hillslope to stream

Research led by Silins, Dyck, Quideau, and MSc graduate Mueller showed that DOC in soil pore water and groundwater was higher after clear-cutting, but little to no impact was evident at the watershed scale due to poor coupling between hillslopes and streams.

Theme 1



"The results coming out of Theme 1, watershed science and forest management are really encouraging. We are seeing significant synergies across most of the ecozones in respect to forest harvesting impacts on water treatability and quality."

ULDIS SILINS
UNIVERSITY OF ALBERTA
CO-PRINCIPAL INVESTIGATOR OF THE *for*WATER NETWORK

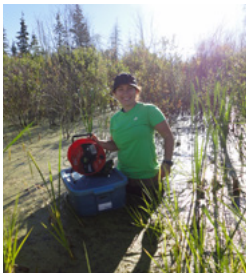
Ecozone: Boreal Plain

The Boreal Plains is a region that is relatively flat, have thick glacial deposits, widespread peatlands, and numerous shallow lakes. The dry climate, topography, and the variability in texture of the glacial deposits cause complex hydrology, with large variability in runoff generation and water quality. Surface water on the Boreal Plains is however generally high in dissolved organic matter (DOM), nutrients, and other dissolved solutes, and results in water quality which presents significant challenges for water treatability. The research conducted in this area is focused on understanding both the spatial and temporal variability in hydrology and water quality, as well as the impacts of land use (e.g., forest harvesting) and other disturbances (e.g. wildfire). Key aspects of water quality that have been focused on include DOM characterization, nutrients, and potential cyanotoxin production.

Hydrology shown to be different than topography in sub-humid, low-relief

Devito, Mendoza, and PhD candidate Hokanson debunk the assumption that in peatland and forest hydrology that water flows from highs (forested uplands) to lows (wetlands/peatlands). Research shows that aspen forests are actually poor sources of water to the larger landscape, and peatlands are the primary water source for runoff. This work demonstrates how water quality and hydrology are coupled and need to be considered in water treatment, especially in complex environments like the sub-humid region of the Boreal Plains.

Theme 1

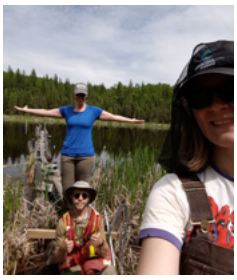


In-stream DOM composition and treatability metrics distinct across ecozones in Canada

We have conducted a comparison of the chemical composition of DOM in streams across forested ecozones of Canada. Led by Olefeldt and PhD candidate Orlova in collaboration with Emelko and Amiri, with input from researchers across all platforms, we used a range of techniques to show that each forested ecozone has its distinct chemical composition of DOM – often associated with differences in soils, climate, topography, and groundwater hydrology. We also found common trends in DOM composition across ecozones, where longer water residence times of water in lakes or larger watersheds cause similar shifts in DOM composition. While the detailed assessment of DOM composition allowed us to assess differences both between and within ecozones, we also found that the simplest measures of DOM composition were the most powerful in predicting several treatability indices, including the disinfectant byproduct formation potential.

Theme 1 Theme 3

Ecozone: Boreal Plain



Aspen harvesting limited impact, wildfire in peatlands increase nutrient mobility

Research by Olefeldt and Devito shows the limited impact of aspen clear-cut harvesting on DOC and turbidity concentrations which is masked by climate, low connectivity and beaver activity. In contrast, wildfire can increase availability and potential mobility of nitrogen and phosphorus, which may have water treatment implications with the increased prevalence of algal blooms. Dissolved organic matter (DOM) however is limited in quantity and quality post-wildfire.

Theme 1

Spatial and temporal variability of DOM in lakes of the Boreal Plains

Devito, Olefeldt, and PhD candidate Pugh monitored the chemical composition of DOM in 35 lakes on the Boreal Plains over 8 years, in order to understand how it changes both in space and over time. Here, surficial geology can substantially affect the variability between lakes, as it influences the connectivity of various terrestrial sources of DOM to the lakes. Neither wildfire nor forest harvesting in the study watersheds appeared to affect DOM in the lakes that were investigated. While DOM composition varied between lakes, the same relative shifts in surface water DOM over time were observed in lakes with and without forest harvest activities in their catchment. Longer-term cumulative (i.e., over 1-2 years) precipitation led to shifts in water residence time and thus the amount of within-lake processing of the DOM. These observations underscore the implications of climate change-associated shifts in precipitation patterns on water quality, and likely treatability.

Theme 1

“To our knowledge, no-one has adequately coupled hydro-chemical models with spatially explicit forest simulation models. We will have a very robust suite of measurements, both in the forests and in the streams, to build and calibrate the models.”

ROB JAMIESON
DALHOUSIE UNIVERSITY
PLATFORM LEAD, ATLANTIC MARITIME

Ecozone: Boreal Shield

The Boreal Shield is the largest of Canada's ecozones and stretches from the Rocky Mountains to the east coast of Canada. It is renowned for its numerous rivers and lakes, its extensive forest cover and a wide range of unique animal species. Research using long-term field monitoring and modeling tools evaluates the immediate (1–3 year) and long-term (15+ years) legacy effects of forest management on drinking water treatability, especially dissolved organic carbon (DOC) and disinfection byproduct formation potential (DBP-FP) in streams.

Boreal Shield research shows scale-related changes in DOC and DBP-FP

Research conducted by Buttle, Webster, Leach, Emilson and MSc candidates Qi and McPhail has explored stormflow and DOC response to harvesting and recovery in a high-relief forest landscape on the Boreal Shield. Observations show DOC concentration increases during stormflow as well as persistent and strong DOC and DBP-FP relationships and high DOC concentrations from harvesting treatments in headwater streams up to two decades following harvest. In collaboration with Emelko and Amiri, they showed that while DBP-FP concentrations appear to decrease with increasing catchment scale, they may still exceed values from headwater catchments. These results have implications for drinking water treatment post-harvest in the Boreal Shield. Current research by MSc candidate Watkins is examining whether such relationships also occur in low-relief forest landscapes that are typical of much of the Boreal Shield.

Theme 1 Theme 3

Ecozone: Atlantic Maritime

Situated within the Acadian Forest Region in Nova Scotia, this research area is home to diverse forest ecosystems. Research seeks to develop a predictive modeling framework to assess impacts of forest management practices on carbon (C) budgets of Maritime watersheds.

Hydro-chemical models of variability of DOC provide insight for water treatment

Research conducted by Duinker, Jamieson, PhD Foster, and MASc Langelaan shows that the concentrations and characteristics of DOC in stream water are variable across the study catchments during the pre-harvest period. Higher levels of DOC increase the costs of water treatment, create taste and odour issues, and contribute to formation of disinfection byproducts. Hydro-chemical models can produce preliminary assessments to test management regimes to lower carbon export to the lake.

Theme 1

Contributing Researchers

Ecozone: Pacific Maritime

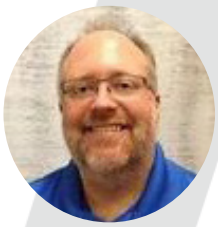
Mark Johnson,
Platform Lead
University of British Columbia

Bill Floyd,
Vancouver Island University

Suzanne Tank,
University of Alberta

Ecozone: Montane Cordillera

Uldis Silins,
Theme Lead
University of Alberta



Miles Dyck,
University of Alberta

Sylvie Quideau,
University of Alberta

Ecozone: Boreal Plain

Kevin Devito,
Platform Lead
University of Alberta

Carl Mendoza,
University of Alberta

David Olefeldt,
University of Alberta

Ecozone: Boreal Shield

Jim Buttle,
Platform Lead
Trent University

Richard Petrone,
University of Waterloo

Ecozone: Atlantic Maritime

Rob Jamieson,
Platform Lead
Dalhousie University

Peter Duinker,
Dalhousie University

Theme 2: Downstream Effects Propagation

Knowledge of in-stream and downstream propagation effects of forest management practices is critical for the provision of safe, secure, drinking water. Evaluating the source and transport of key water quality drivers of treatability (turbidity, dissolved organic carbon, phosphorus, fine sediment) helps inform planning for the treatment and provision of water supplies across Canada.

Fine sediment tracing helps track contributions to algal blooms

Researchers Stone, Collins, and Krishnappan in collaboration with Emelko and Silins demonstrated the utility of sediment source fingerprinting as a tool to identify sources of fine sediment upstream that contribute to deteriorated water quality in downstream aquatic environments, such as reservoirs. A recent paper led by International *for*Water research partner Collins, is a critical review of current state-of-the-art sediment source fingerprinting practices which supports a global refinement of the process and standardization of methods used to evaluate the role of landscape disturbance pressures on water quality.

Theme 1 | Theme 2 | Theme 3

Models and meta-analysis highlight landscape disturbance impacts

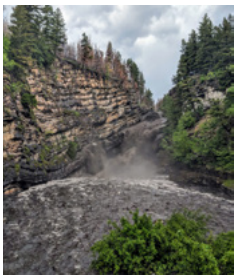
Basu and PhD candidate Hampton conducted a meta-analysis of the effect of landscape disturbance on stream nitrogen, phosphorus and carbon concentrations, which are generally understood to increase in response to sufficient disturbance. They also developed a model coupling hydrology, forest growth, and water quality, with the goal of using the model to simulate how forest disturbance and a changing climate can increase stream nutrient concentrations, and thus impact drinking water treatability.

Theme 2

Road surfaces are a highly variable source of phosphorus

Road surfaces in forested source water regions are linear features that can be important sources of phosphorus to receiving water bodies. Notably the levels of phosphorus on road surfaces are related soil texture, the type and extent of landscape disturbance, slope and hydroclimatic conditions. In a study of road surface composition across Canada, Anderson and MSc candidate Humeny reported that phosphorus levels are highly variable, but higher phosphorus concentrations are associated with road surface condition and weathering processes. Erosion risk from roads is higher in western Canada than in eastern Canada because of differences in soil texture and erodibility.

Theme 2



Sediment-associated phosphorus concentrations unchanged by harvesting

Stone and Collins, in collaboration with Silins and Emelko found no significant change in particulate phosphorus forms and suspended sediment concentrations between study sites located above and below harvesting treatments—partial retention, strip cut, clear-cut—in southwestern Alberta. In contrast, wildfire can increase concentrations of fine sediment-associated bioavailable phosphorus, which can be propagated downstream over long distances to reservoirs. Stone and MSc candidate Watt, in collaboration with Emelko and Silins further showed that anthropogenic and climate-exacerbated landscape disturbances converge to alter bioavailable sediment-associated phosphorus stored in the gravel bed of an oligotrophic river flowing through a watershed under multiple resource extraction, climate, and typical urbanization pressures, thereby underscoring the importance of including climate change disturbance effects in cumulative watershed effects assessment.

Theme 1 Theme 2 Theme 3

Collaborative partners support comparative studies

In order to conduct cross-ecozone comparative studies, research relies on partners from across the country to provide samples to provide data for analysis. Capital Regional District on Vancouver Island, The City of Calgary in Alberta, the Canadian Forest Service in Ontario, Halifax Water in Nova Scotia all work in collaboration to provide samples and data for research related to downstream propagation of disturbance-related impacts on water quality and treatability.

Theme 1 Theme 2 Theme 3 Theme 4

Calgary

CRD Making a difference...together

Halifax Water

Natural Resources Canada Ressources naturelles Canada

Canada

Theme 3: Drinking Water Treatability

Increasingly severe natural disturbances create new challenges for drinking water treatment. This research focuses on enabling drinking water providers to anticipate, respond to, and adapt to these challenges. It also helps watershed scientists better describe the potential implications of landscape disturbances to the treatment of drinking water. From large to rural, remote, and marginalized communities with various treatment technologies and different response capacities, this work is contributing to ensuring safe drinking water for all.

Source water alkalinity as a critical component of drinking water treatability assessment

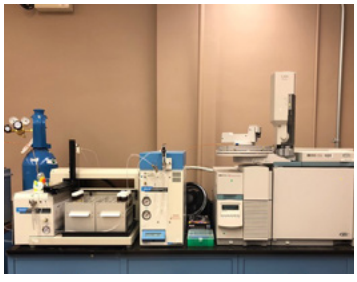
Research conducted by Emelko, PhD candidates Skwaruk and Bahramian shows that the interrelationships between not only dissolved carbon and turbidity, but also alkalinity must be considered to evaluate the drinking water treatability and especially coagulation efficiency implications of watershed disturbances.

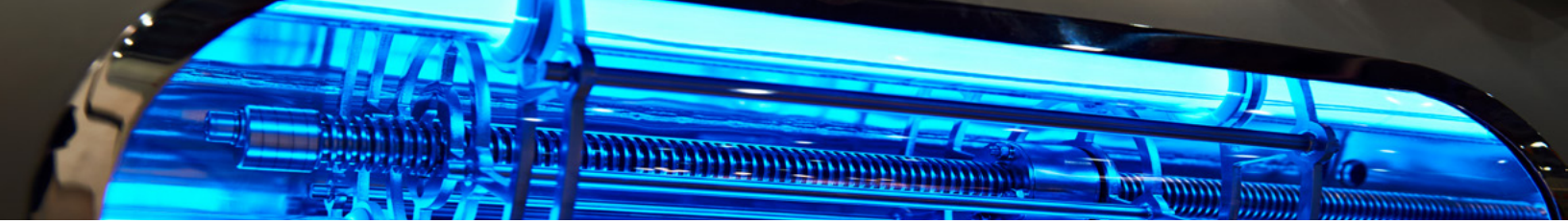
Theme 3

Anticipating treatment impacts of dissolved carbon

Despite widespread efforts to develop various approaches to characterizing aquatic carbon, Emelko and Amiri confirm that the simple analysis of UV_{254} (UV absorbance at 254 nanometers) remains the best indicator of disinfection byproduct formation potential (DBP-FP) when water is chlorinated because it reflects both dissolved carbon concentration and carbon aromaticity (character). Not only does DBP formation potential increase with watershed disturbances, so do membrane biofouling and distribution system regrowth potentials. This results in greater backwashing and distribution system disinfection needs, respectively. Interestingly, algal proliferation and associated toxin formation potential appears to decrease DBP formation potential. This may be because algae transforms carbon or contributes algal organic matter so that it is not the same precursor material.

Theme 1 Theme 3





Rural, Remote and Marginalized (RRM) community drinking water security in Canada

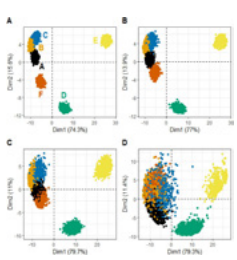
Emelko, Dickson-Anderson, and MASc candidate Blackburn have developed a framework for describing and advancing on the promise of green technologies in drinking water treatment. This framework can help to better describe and respond to preferences and values related to drinking water treatment, especial in RRM communities. Dickson-Anderson, Schuster-Wallace, and PhD candidate Deb Nath share that drinking water advisories (DWAs) are insufficient as the sole measure of drinking water insecurity in Canada. Large gaps exist for those who do not have piped water (and thus are not subject to DWAs); many are more drinking water insecure than those who have piped water but are subject to frequent or long-term DWAs. A framework for drinking water security in small, RRM communities has been developed along with indicators and metrics. The framework was expanded beyond the typical treatment and distribution system performance evaluations by increasing the breadth of literature scoped and culminated in a comprehensive and flexible list of indicators for assessing drinking water security from headwater to consumer. The framework has multiple applications towards enhancing drinking water security in RRM communities including risk awareness and mitigation, selecting appropriate technologies, prioritizing investments, and assessing performance.

Theme 3

Improved cyanobacterial communities sampling

Cyanobacteria can be a challenge to treat when present in source water. Research led by Müller, Emelko, and PhD candidate Cameron in collaboration with Webster, Stone, and Buttle indicate that cyanobacteria are present year-round in northern temperate lakes, although diversity of the communities can change month-to-month. The work shows that microbial diversity can differ substantially among different locations within a lake or reservoir and within the water column. Nonetheless, persistence and early seasonal increases in relative abundance of potentially toxic cyanobacteria provide evidence that climate change is protracting the vernal window (i.e., a period that marks the end of winter and the start of the growing season during which rapid shifts in ecosystem energy, water, nutrient, and carbon dynamics occur) in northern temperate lakes.

Theme 1 Theme 2 Theme 3



Rarefaction of DNA data reduces errors in estimations of cyanobacteria diversity

Cutting edge research in understanding microbial communities using 16S rRNA gene community sequencing raises issues in the analysis of these data. Research led by Müller, Emelko, and PhD candidate Cameron shows that repeated rarefaction of DNA sequence data reduces the potential for errors in estimations around alpha and beta diversity (i.e., indicators of the number of species and differences between species' abundance). Rarefying also normalizes library sizes by subsampling and enables appropriate context for understanding the results for water treatment.

Theme 3

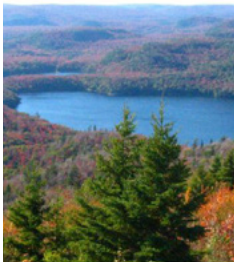
Theme 4: Resource Economics

With the rise of natural disturbances and impacts on drinking water sources, the cost of treating water is becoming increasingly expensive in recent history, creating problems for municipalities large and small. This research is looking at the direct and indirect economic implications of contemporary forest management technologies to better support source water protection and water security.

Green infrastructure may be cost-effective for water treatment

Research led by Brouwer and PhD candidate Pan examined how green infrastructure may be cost-effective, but also introduces uncertainties compared to grey infrastructure, while the longer term benefits may be quickly discounted over time at a positive discount rate. The higher the discount rate, the higher the benefit gained in the short-term over future benefits, discouraging decision-makers to invest in green infrastructure that may take time to become effective. This finding has implications for water treatability and the economic value of water quality benefits, and hence for green infrastructure to be a sustainable option for water treatment in increasingly urbanizing watersheds across Canada.

Theme 3 Theme 4



Significant relationship detected between land cover, land use, and the price of water as a proxy for water treatment costs

In Ontario, a significant relationship between land cover, the price of water as a proxy of water treatment costs and adverse drinking water events was detected using a spatially explicit economic analysis of water treatment data by Brouwer and PhD candidate Pan. The relationship showed forested areas have a significant negative impact on the cost price, suggesting it reduces the water treatment costs, and on the number of reported water incidences across the province.

Theme 3 Theme 4

@forWaterNetwork www.forwater.ca

Contributing Researchers

Theme 2: Downstream Effects Propagation

Mike Stone,
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Axel Anderson,
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Theme 3: Drinking Water Treatability

Monica Emelko,
Theme Lead
University of Waterloo

Sarah Dickson-Anderson,
McMaster University

Kirsten Müller,
University of Waterloo

Theme 4: Resource Economics

Roy Brouwer,
Theme Lead
University of Waterloo

Vic Adamowicz,
University of Alberta

Diane Dupont,
Brock University

Thank you, contributing partners!

Canadian Water Network
Canfor
Capital Regional District
City of Calgary
Eastern Research Group
Eawag aquatic research
EPCOR
Government of Alberta
Government of Nova Scotia
Government of Ontario
Halifax Water
National Collaborating Centre for Environmental Health
Natural Resources Canada
PESFOR-W COST Action
Regional Municipality of Wood Buffalo
Rothamsted Research
Spray Lake Sawmills
The Water Research Foundation
West Fraser
Weyerhaeuser